NATIONAL BUREAU OF STANDARDS REPORT

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Field Tests
of
Airfield Lighting Cable Connections

By
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U. S. DEPARTMENT OF COMMERCE
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For
Bureau of Naval Weapons
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ABSTRACT

This report presents the results of field tests of cable connectors and splices which had been buried for 42 to 50 months. One type of connector and two types of splices designed for use on airfield lighting cable were included in the tests. Each type of connection was made by a different manufacturer. The tests included periodic measurement of insulation resistance and a visual inspection of the connections. The insulation resistance of each connector or splice was several thousand megohms. Considerable leakage developed at the ends of the cables which were taped and buried. The performance of the connection depends on the method and care used in preparing the connection, on the method of installation, and on the type of connection.

1. INTRODUCTION

Cable connections are tested for conformance to the requirements of applicable specifications to determine quality of materials and workmanship. However, maintenance reports from the airfields indicate that the connections obtained under these specifications are not always satisfactory in service. Field tests were therefore undertaken to determine the performance of several types of connectors and splices, the change of the insulation resistance of these connections with time, and methods of installation which will reduce the number of connection failures. To obtain the data, it was necessary to continue the tests for several years.

2. MATERIALS TESTED

Thirteen test units were used in these tests. The units are identified in table 1. Six connections were of a type using style E, assembly No. 2540-A1 connectors manufactured by A'G'A Division (now Elastimold Division) of the Elastic Stop Nut Corporation of America. These units were prepared as follows:

1. The ends of sections of #8 AWG solid, 5000-volt, type MIL-C-4921 cable to which connectors were to be installed were cleaned with carbon tetrachloride, the insulation and sheath were pencilled for approximately one inch, and the fittings were crimped to the conductor.

2. The fittings and cable ends were pushed into the connector housings, the disposable assembly pin and protective sleeve were removed, and the excess insulating jelly was wiped off.

3. The plug was inserted into the receptacle and two turns of plastic electrical tape were wrapped around the joint.

Three test units were of a type using "Scotchcast" splicing kits No. 82-A manufactured by Minnesota Mining and Manufacturing Company. These units were prepared as follows:

1. The conical ends of the end caps were trimmed to fit the #8 AWG solid, 5000-volt, type MIL-C-4921 cable firmly and an end cap was slipped on the end of each section of cable. The molded body cylinder was then slipped on one section of cable.

2. The ends of the cable which were to be spliced were cleaned with carbon tetrachloride, the conductor was spliced with "Scotchlok" type L spring connectors, the insulation was pencilled back for one-half inch, and the sheath was cut back for another half inch on each side of the splice.

3. The insulation and outside of the cable over the length of the splice were roughened and dressed until smooth with the abrasive strip in the kit, and the mold was assembled and centered on the splice with the standpipes up.

4. The "Unipak" resin and activator were thoroughly mixed and poured into the mold, pouring in at the lower standpipe until the resin was well up in the upper standpipe.

5. After the mold was cooled over night, the standpipes were cut off.

Four test units were splices of a type made with the Joy Manufacturing Company's series X1604-8 portable vulcanizer. These units were prepared as follows:

1. The sheath and insulation were removed from one inch of conductor on the ends of sections of cable which were to be be connected. Type MIL-C-5136, #8 AWG solid, 5000-volt cable was used for these splices in order to fit the vulcanizer mold. The insulation and sheath were pencilled for three-fourth inch from the stripped ends.

2. The ends of the conductors were joined by crimping splicing sleeves with a Thomas and Betts model WT-115 hand staking tool.

3. The cable jacket was thoroughly roughened with a file for three inches from the end, the cable was cleaned with carbon tetrachloride, and a light coat of Joy 319,763 neoprene cement was applied to the roughened and pencilled portions of the cable and allowed to dry.

4. The exposed conductor and splicing sleeve were tightly wrapped with Joy 319,775 insulating rubber tape to a thickness equivalent to that of the original cable insulation and over this tape Joy 319,777 jacketing rubber tape was wrapped evenly to form the shape of the mold cavity.

5. Mold halves #324,521-3 were fastened in the vulcanizer body and after the mold was preheated to 300°F it was wiped lightly with Joy 302,519 "Apiswax."

6. A double thickness of 319,777 jacketing tape was placed along the length of the splice at the base of each mold center cavity. The splice was centered in the mold and allowed to soften for three minutes. Then the mold was clamped to close the jaws to within one-fourth inch, and after an interval of one minute, the jaws were completely closed.

7. The splices were cured for 30 minutes at 300°F, removed from the mold to cool, and trimmed of excess material.

NOTE: The insulating tape, jacketing tape, and neoprene cement were fresh stock, obtained directly from the manufacturer.

3. TEST PROCEDURE

An area of ground was selected where only the topmost layer of soil had been previously disturbed. A section approximately 10 feet by 10 feet was excavated to a depth of two feet. The samples were arranged on the floor of this hole in such a manner that the connectors and cables were separated by several inches with no crossing of the cables. One free end of each test unit was brought up into the instrument shelter. The other free end of two of the samples was also brought into the shelter. The other free ends of the remaining samples were cleaned and taped with plastic electrical tape or a combination of rubber and plastic tapes. (See table 1 for identification and installation information.) A clamp was fastened around each of the cables between the taped end and the connection and all of these clamps were connected to a driven ground rod. Then the hole containing the test samples was filled with soil.

The cable ends which were brought into the shelter were not taped. In the latter part of the tests a guard ring was placed on each of the units between the end of the cable and the soil.

To determine the effects of electrical potential on the performance of the connectors, the high-voltage output of a 120/2400-volt, 100-volt-ampere instrument transformer was connected between ground and three of the A'G'A test units and one of the Scotchcast units and applied continuously after December 1960. The test samples did not connect the transformer to a load; thus, only leakage current flowed through the connector. The effect of this potential, if any, would be indicated by the insulation resistance values obtained.

The insulation resistance of each test connection was determined by applying the direct-current voltage from a TAKK high-voltage limited-current insulation tester to the conductor and measuring the leakage current. The insulation resistance is the voltage applied divided by the leakage current. The TAKK tester was modified to incorporate a guard circuit to exclude from the measurement the leakage at the open end of the cable. The meter of the TAKK tester was not sensitive enough to indicate accurately the leakage current of a single connection and a General Radio type 1230-A direct-current amplifier and electrometer was used to read the leakage current. In order to obtain a stable average reading, a resistor-capacitor filter was used to smooth the current. The insulation-resistance, leakage-current measurements were made each spring and autumn near the end of the rainy season and of the dry season. The applied test voltage was 15,000 volts, as required in Specification MIL-C-7192, during the first year, and 5000 volts, as recommended by ATL 5012 for old circuits, after that time.

In June 1963, after the A'G'A and Scotchcast units had been buried for over four years and the Joy units a little less than four years, all of the connectors were uncovered and inspected for evidence of deterioration. At this time the ends of the test samples which had previously been buried were brought into the shelter where the guard ring could be used to eliminate from the measurements the leakage current across these ends. Then the test samples were buried again. Tests are continuing.

4. TEST RESULTS

4.1 Measurements. The results of the insulation-resistance measurements are given in table 1. The values shown are not consistent throughout because of changes in the measurement procedures and in the installation. The 2/59 measurements were for a special test after two of the connectors had been submerged in tap water for 105 days. The 4/59 measurements were the initial measurements after nine units were buried. The meter used for the 4/59 measurements was unsatisfactory

for indicating resistances greater than 15,000 megohms. Insulation resistance measurements made without the use of a guard ring are not reported, except initial measurements where surface leakage was not a factor. The guard circuit at the open end of the cable was used for the measurements tabulated for 11/60, 3/61, 3/62, 9/62, and early 6/63. These measurements are not affected by the leakage across the ends of the cables which were brought into the shelter, but are affected by the leakages at the taped and buried ends of the cable. The later 6/63 measurements were made after the visual inspection, with both ends of all test units brought into the shelter. For these measurements, guard circuits were used at both ends of the cable. The values given are thus the insulation resistances of the connections and sections of cable between the guard rings only. The effects of leakage at the free ends of the cable have been eliminated.

4.2 Visual Inspection. At the inspection of the test samples after they had been buried for 42 to 50 months, none of the connections showed any visual evidence of leakage. However, test unit XVII had a leakage path from the taped end of the cable to the guard ring. This was the reason for the low insulation resistance values for this test unit. Test unit XVIII had developed a leakage path by the guard ring inside the shelter which caused the earlier low insulation resistance values for this unit. None of the test units had visible evidence of leakage until after the tape was removed from the buried end of the cable. When the tape was removed from the pencilled cable ends, an area showing evidence of leakage or arcing was found. A much smaller area was found on the tape from the square-cut cable ends, indicating little, if any, leakage.

5. DISCUSSION OF RESULTS

After these test connections had been buried for 42 to 50 months, the insulation resistance of each of the connectors and splices, including the sections of cable between guard rings, was well above the 3000 megohms minimum required by Specifications MIL-C-7192 and L-823. Accurate values of the initial insulation resistance of several of the connectors and splices are unknown, but values for two of the A'G'A connectors are available. For these two connectors the insulation resistance had decreased from 60,000 and 62,000 megohms to 42,000 and 50,000 megohms, respectively. The average of the insulation-resistance values for the A'G'A connectors at the later 6/63 measurement was 33,000 megohms. This was approximately one-half the value of the average insulation resistance of 62,000 megohms for a group of A'G'A connectors after they had been submerged in tap water for 30 days during another test.* Specific values were not available for comparison of the other

*NBS Report 21P-39/58, Physical and Electrical Tests of Connectors for Airport Lighting Cable.

types of splices, but the measurements during these field tests indicate that the insulation resistance decreased similarly.

Since all the test units had resistances considerably higher than the 3000 megohms minimum required in the specifications, the variations in the values may be of minor importance for determining the effectiveness of the type of connection. Also, since test units X and XII, which have much shorter lengths of cable, had the lowest leakage currents - highest resistances - of the type A'G'A connectors, much of the measured leakage may be in the cable instead of in the connections.

Except for the later 6/63 measurement, the changes in the insulation resistance values apparently indicate the amount of leakage at the buried end of the cable instead of leakage at the connections. To eliminate this variable effect, both ends of the cable have now been brought into the shelter for future measurements. The guard circuit can now be used to eliminate the effect of leakage at both ends of the cable.

There was no conclusive evidence that either plastic electrical tape alone or a combination of rubber tape and plastic tape provided better protection for the buried ends of cable. Of those units with the ends taped and buried, the samples which had the ends cut off squarely had less leakage current and less evidence of leakage than did the samples which had the sheath and insulation pencilled before taping. This indicates that the maintenance of insulation resistance obtained by sealing the end of the cable with tape over a sharp corner of insulation is greater than that obtained by pencilling the cable to produce a longer leakage path.

The test units which had the 2400 volts potential applied continuously did not show greater insulation deterioration than those without voltage. The tests did not evaluate the effect on the connections and cable of current being delivered to a load. The heating from the current may adversely affect the insulation if the voltage drop across the connection exceeds specification limits.

6. CONCLUSIONS

1. All three types of connections, properly prepared according to the manufacturer's instructions, and buried for several years, exceeded the 3000 megohms minimum insulation resistance required by Military Specification MIL-C-7192 and FAA Specification L-823. The insulation resistances of the test connections and sections of cable had decreased to approximately one-half of the initial values after four years, but still ranged from 8,000 to 50,000 megohms.

2. The continuous application of electrical potential up to 2400 volts did not adversely affect the insulation of these connections.

3. Insulation breakdowns at connectors or splices on installed airfield lighting cable may be caused by lack of care and cleanliness in making the connection, improper procedures in installing the cable, stresses from frost heaving, mechanical stresses, or the quality of the connector or materials for the splices.

4. When the end of a cable must be buried and cannot be protected by a suitable weatherproof container, tape may be used to seal the end. However, the leakage across taped ends in this test was greater than the leakage in the connectors. Either plastic electrical tape or a combination of plastic tape over rubber tape may be used. When tape is used, a square cut end is better than a pencilled or tapered end for reducing current leakage.

7. RECOMMENDATIONS

1. In order to determine the performace of these connections during additional time, the field tests of these samples should be continued using the test methods of "later 6/63."

2. If the need for better protection of free ends of buried cable is great, a cap should be developed to provide such protection.

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Table 1. Installation Information and Results of Insulation Resistance Measurements for Three Types of Cable Connectors

Unit Identification	Date Prepared	Length of Cable Sections	Shape of Free End of Cable	Insulating Tape Over Free End of Cable	Date Test Began	Resistance Values Given in Megohms for Date of Measurement: 2/59[1]	4/59[2]	11/60	3/61	3/62	9/62	Early 6/63	Later 6/63[3]	Average Later 6/63
A'G'A Style E. Assembly No. 2540-Al Connectors														
X	11/58	2 feet	Square cut	Plastic only	3/59	60,000	>15,000	83,000	31,000	100,000	45,000	42,000	42,000	
XII	11/58	2 feet	Square cut	Plastic only	3/59	62,000	>15,000	4,100	4,400	3,700	1,600	6,700	50,000	
XV	3/59	8 feet	Pencilled	Plastic over rubber	3/59		>15,000	4,100	3,500	1,500	550	4,400	23,000	
XVI	3/59	8 feet	Square cut	Plastic over rubber	3/59		>15,000	28,000	8,200	28,000	17,000	7,600	14,000	
XVII	3/59	8 feet	Pencilled	Plastic over rubber	3/59		>15,000	120[4]	90[4]	100[4]	70[4]	170[4]	36,000	
XVIII	3/59	8 feet	Pencilled	Plastic over rubber	3/59		>15,000	800[5]	3,000[5]	510[5]	290[5]	83,000	17,000	30,000
Scotchcast No. 82A Splice Kit Splices														
XIX	3/59	8 feet	Pencilled	Plastic over rubber	3/59		>15,000	100,000	81,000	33,000	33,000	10,000	23,000	
XX	3/59	8 feet	Pencilled	None, end not buried	3/59		>15,000	100,000	250,000	230,000	71,000	62,000	33,000	
XXI	3/59	8 feet	Pencilled	None, end not buried	3/59		>15,000	77,000	250,000	53,000	16,000	12,000	7,900	21,000
Joy Vulcanized Splices							4/60							
A	10/59	8 feet	Square cut	Plastic over rubber	11/59		62,000	2,000	10,000	8,200	10,000	8,200	29,000	
B	10/59	8 feet	Square cut	Plastic over rubber	11/59		56,000	50,000	3,700	7,600	28,000	23,000	33,000	
C	10/59	8 feet	Square cut	Plastic over rubber	11/59		83,000	50,000	36,000	10,000	6,000	8,200	56,000	
D	10/59	8 feet	Square cut	Plastic over rubber	11/59		71,000	21,000	9,100	8,100	3,700	8,200	50,000	42,000

1 Measured after being submerged in tap water 105 days before burying.

2 Initial measurement after burying; inadequate meter sensitivity for more accurate measurement.

3 Measured after both free ends of all units were inside shelter.

4 This specimen had developed a leakage path from the buried free end of the cable to the buried guard circuit.

5 This specimen had developed a leakage path from the free end of the cable inside the shelter past the guard circuit to ground.

Insulation resistance measurements made without the use of a guard ring are not reported, except initial measurements.

Test specimens XII, XVI, XVIII, and XIX had 2400 volts applied continuously after 12/60.

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